Background Information on Simulation Created for
Lesson 5: Eat and Be Eaten: Prey as Predator, Predator as Prey

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in collaboration with the Creative Learning Exchange

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Lesson 5: Eat and Be Eaten: Prey as Predator, Predator as Prey

Note: This lesson builds on Lesson 4 – Waves of Change: Predator-Prey Dynamics in the Oscillation curriculum created for the Complex Systems Project. Lessons 3 - 5 work together to show how a population in isolation can experience growth or decline, but not oscillation (Lesson 3). Further, it is only when considering a population in relation to a wider system boundary, either interacting with another population (Lesson 4) and/or a food supply (Lesson 5), that we have the structure necessary to produce cyclic behavior.

While the screen images, role-playing description and parameter settings presented in this document refer to the C-level simulation, much of the information is still relevant to the A- and B-level simulations.

Contents

Introduction

How do predator-prey cycles occur in nature? Biologists do not always agree on what causes such cycles (and some dispute that they even exist). Where cyclic behavior patterns have been observed, one hypothesis is that the environment creates a tight dependency between predator and prey. Lesson 4 of the Oscillation curriculum presents a simulation of two populations that are locked in such a relationship. The parameters for this simulation have been inspired by the wolves and moose of Isle Royale.

Another hypothesis for the appearance of predator-prey cycles is that a 3-level relationship is at work. Not only is a population of prey animals limited by their main predators, but their numbers also decline due to reaching the limits of their food supply. They are, in essence, squeezed from both top and bottom in the food chain.

The model of Lesson 4 shows that a prey population can exhibit logistic (S-shaped) growth, smoothly reaching the carrying capacity of their environment, when the predator population has been removed (through hunting, disease, etc.). The model in Lesson 5 discussed in this background document adds a "biomass" component to the model of Lesson 4, to represent a food supply for the prey animals. The addition of this third layer allows students to experiment with overshoot-and-collapse behavior when the prey population is unrestrained by predators. The prey population can oscillate due to interaction with the predator population, and also due to interaction with its own food supply.

Lesson 5 is a role-playing simulation. Students play the role of "rookie" Wildlife Manager; their on-the-job training is to investigate the ecosystem they will be managing by experimenting with this simulation. They are allowed to issue hunting licenses for prey and tags for predator removal. Through various modes of interaction with the simulator ("Experiment freely," "Pause every 5 years" and "Real-world scenarios") they can formulate a strategy for managing this oscillatory system.

Overview of Model Behavior

The Default Behavior Pattern

To display the default behavior mode of the simulation, make sure "Experiment freely" is green and click the "Run" button without making any changes to the slider bars (see Figure 1). There are seven pages of graphs. Click the white triangle in the lower left corner of the graph to page through them. Pages 2 – 4 and 6 – 7 are comparative graphs. Each time you click the "Run" button to simulate the model, the comparative graphs will show the new run in a different color. Click the "Reset" button to clear the graphs and reset the parameter values to their default settings.

Please note that when in "Experiment freely" mode, it is possible to change the sliders while the simulation is running. Another alternative is to click the "Pause" button to pause the simulation at any time, in order to make changes to the sliders or simply to evaluate what is happening.

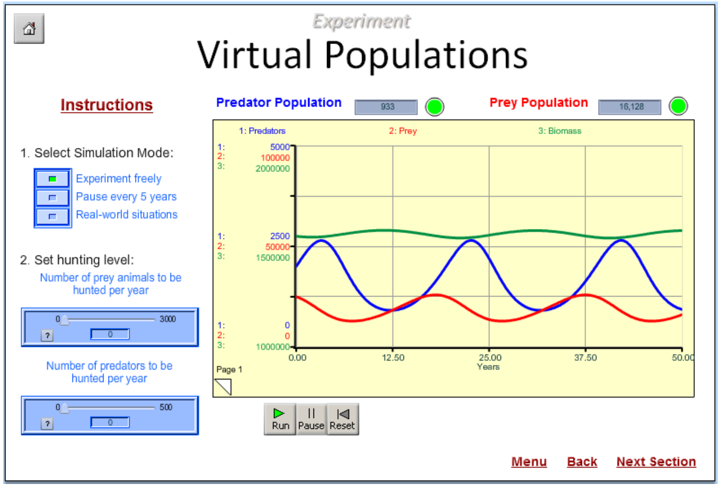

Figure 1: The default behavior of the model.

The **Instructions** link tells students “there is no guarantee” that the number of hunting licenses they issue will result in successful kills. (The reason is that the density of the prey animals has an effect on hunter success just as it does in real life.) Students may also notice that Page 5 of the graph shows “Hunters desired level of hunting” to be 1500 animals per year (after they’ve run the simulation at least once). These clues give an indication of a starting point for experimenting with hunting levels.

Taken together, the Introduction material and the graphs explain the situation the rookie Wildlife Managers are being asked to address. The area under their management has not been open to hunting in the past. The populations of prey and predators fluctuate over time, yet the prey animals are typically healthy, with a high average lifespan, due to the abundant biomass. The peaks in the cycles tend to irritate the human population that lives around the wilderness management area. Residents are scared of predators and fear for their own safety and that of their pets. Farmers cannot afford to lose livestock to predators. A high prey population also causes problems because the animals trample crops, destroy gardens, cause accidents on the roads, and so on. Can hunting be used to improve the situation?

Experiment Freely

A typical run that students might try in “Experiment freely” mode is to set the slider for “Number of prey animals to be hunted per year” to 1500 for the entire length of the simulation. This is a logical setting, but it actually destabilizes the system slightly and does not consistently provide the hunters with their desired level of hunting. Figure 2 shows the Control Panel with this change made.

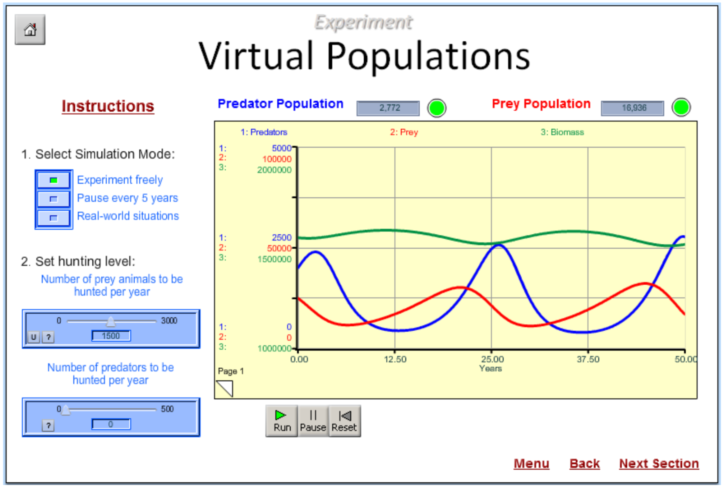

Figure 2: The behavior created by changing the slider for prey hunting to 1500 for the whole simulation.

To see this run compared to the default behavior run, check Pages 2, 3 and 4 of the graph. You will see that the predator population dips lower and stays lower than the default run for much of the simulation, but also shows steeper increases on the upswing of the cycles. Furthermore, it appears that the cycles peak at progressively higher levels, although not by much. The prey population peaks later and higher in this run compared to the default run; biomass is only slightly affected by the change. On Pages 6 and 7, you will see that there are no changes from the default run – the prey population still enjoys high nutrition and the same average lifespan.

Page 5 of the graph shows why the policy of always hunting 1500 prey animals cannot be considered a complete success. This graph shows “Prey killed by hunters” and “Hunters desired level of hunting,” as seen in Figure 3 below.

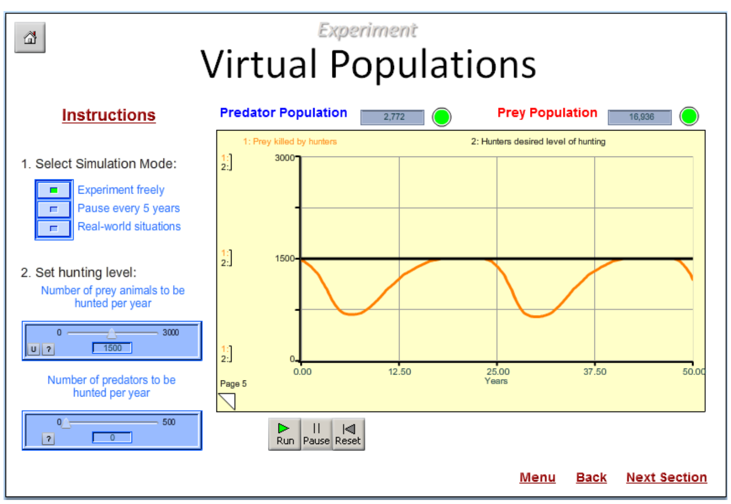

Figure 3: Hunting versus desired hunting when 1500 licenses are issued.

If this were a real-life situation, hunters would likely give a harsh assessment of the job the Wildlife Manager is doing. They may not realize that the prey population oscillates over time, and that during the low cycles of the oscillation, the population density is low, and therefore the animals are harder to find and kill. In fact, hunters may even think that mismanagement of the herd is the cause of the poor hunting! It would be easy for them to surmise that if the management job was "done right" then they would always get their trophy animal.

Pausing Periodically

A real Wildlife Manager will not simply set a certain level of hunting and then never reevaluate the situation over a 50-year timespan. The "Pause every 5 years" mode adds a layer of realism. It represents a planning cycle whereby a manager or management team reflects on results achieved and decides how best to move forward. In real life, such planning is often updated between the extensive reviews every five years. In the case of wildlife management, however, we can reasonably assume that there is at least a few years' delay between reviews because it takes time to do the fieldwork necessary to evaluate the size and health of wild populations.

It is important to note that students may or may not operate the simulation with a particular goal in mind for the prey population. For example, they may move the sliders up or down when the simulation pauses just to "see what happens." This is likely to result in oscillations that are "wild" and perhaps even the demise of the predator population. Without predators, even a high level of hunting for prey will not prevent the population from overshooting the capacity of the biomass to sustain them. Students should be encouraged to check Pages 6 and 7 of the graph to understand the health of the prey population. Hunters do not want to hunt small, weak animals!

An example run using "Pause every 5 years" mode is shown in Figure 4.

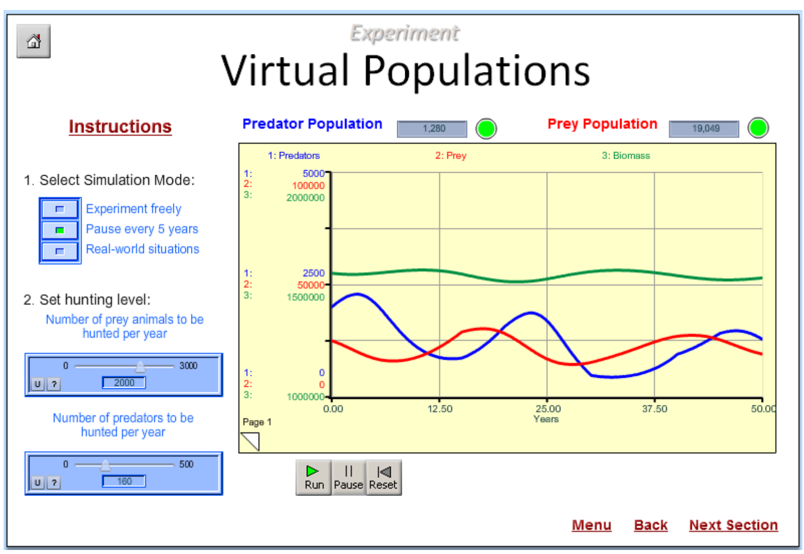

Figure 4: An example of using "Pause every 5 years" mode.

The simulation ended with a prey population that was still oscillating, but the ups and downs seemed more drawn out at the end of the 50 years than at the beginning. The strategy used was to vary the number of predator tags issued to keep predators relatively low, and not allow hunting of prey for the first 15 years to build up the population. At that time, the population was considered large enough to allow prey licenses to be set to 2000 per year for the rest of the simulation. The hunting graph is shown in Figure 5.

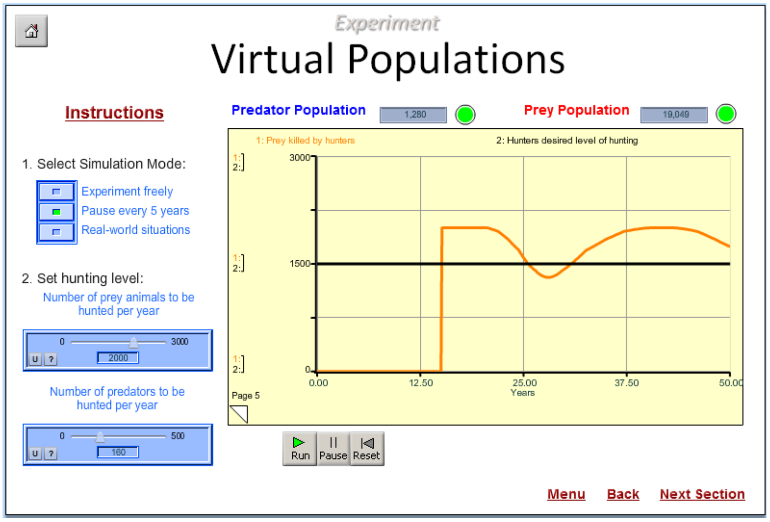

Figure 5: Would this Wildlife Manager be considered skillful in the eyes of hunters?

The first 15 years probably would have been tough for this Wildlife Manager! This person had a goal of building up the prey population and stuck with it. Even though hunting could be considered good for the rest of the simulation (prey were healthy and kept their high average lifespan), students may have opinions as to how likely it would have been for this person to be fired had this been real life.

Students' results will vary widely. It is important for them to think through a strategy and how they will execute it. Success should be measured on not only how satisfied hunters likely are, but also how healthy the rest of the ecosystem is allowed to be.

Real-world Situations

Setting a strategy and making adjustments along the way is good management practice. It becomes more difficult when various groups of people want to have their say in how you're doing your job. The "Real-world situations" mode is meant to test resolve and show that complex systems are tough to manage. The bombardment of information and pressure that comes from "outside" can serve to muddy the waters for a manager on the "inside" of the system. In real life, this is a contributing factor to a misunderstanding of observed dynamic behavior. For instance, in a real system that oscillates, it can be perceived that the buffeting effects of outside events and perturbations are actually what cause the oscillation. What's really happening, however, is that the system oscillates because of its structure.

Figure 6 shows the results of a not-very-successful run using "Real-world situations" mode. The manager started conservatively with low levels of hunting for both populations. As messages kept appearing to indicate hunter frustration, this person did increase prey hunting significantly. However, when disease and drought hit the area, hunting was lowered again. The slow recovery of the prey animals gave the manager a false sense of security about the predator population. When the predator population increased dramatically, the manager tried to compensate by issuing more predator tags. The damage was already done; prey numbers dropped due to the large predator population and the manager had to endure messages that indicated an angry resident population was complaining about the predators.

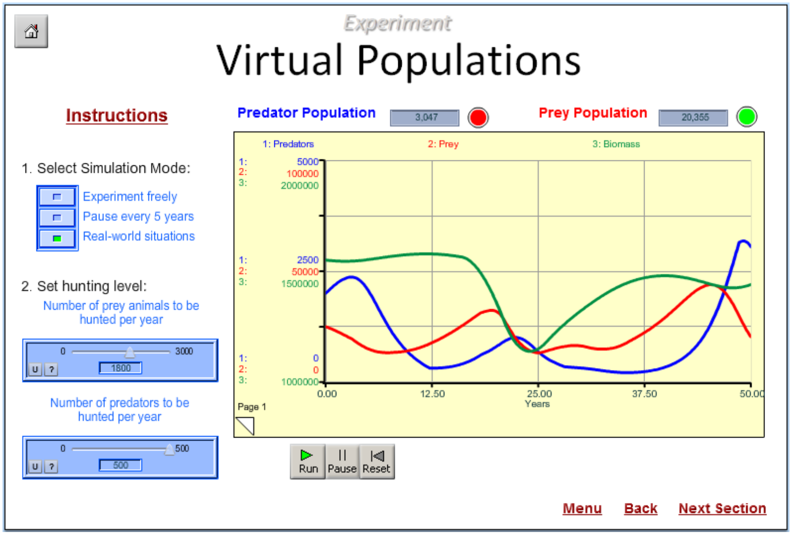

Figure 6: Using "Real-world situations" mode will generate interesting results!

Figure 7 and Figure 8 show how even though hunting was high for some of the time, hunters were not always shooting healthy, robust animals. In fact, we could even infer that hunters would have been frustrated with the hunting opportunities for most of the simulation. Offering double the number of licenses in a mad dash to control the population growth or to make up for past poor hunting is not indicative of a skillful manager. Even worse, the simulation ended with a predator population that was too large for residents and farmers to feel comfortable.

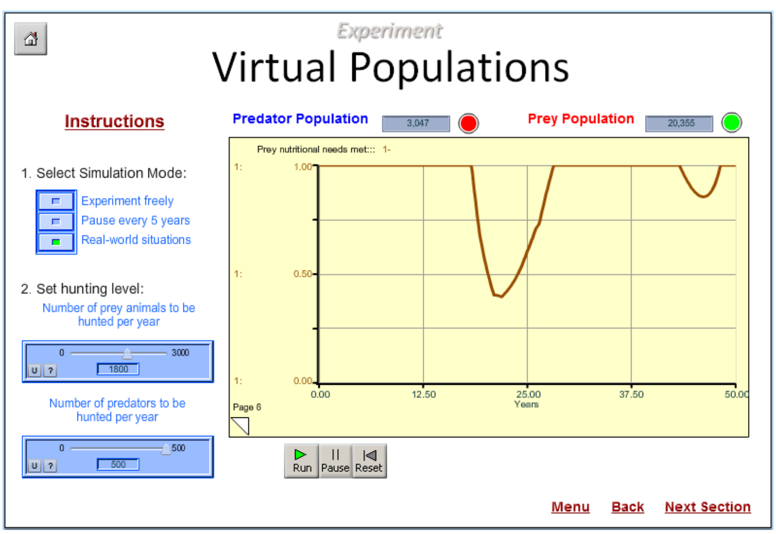

Figure 7: The explosion of prey meant that animals could not find enough to eat.

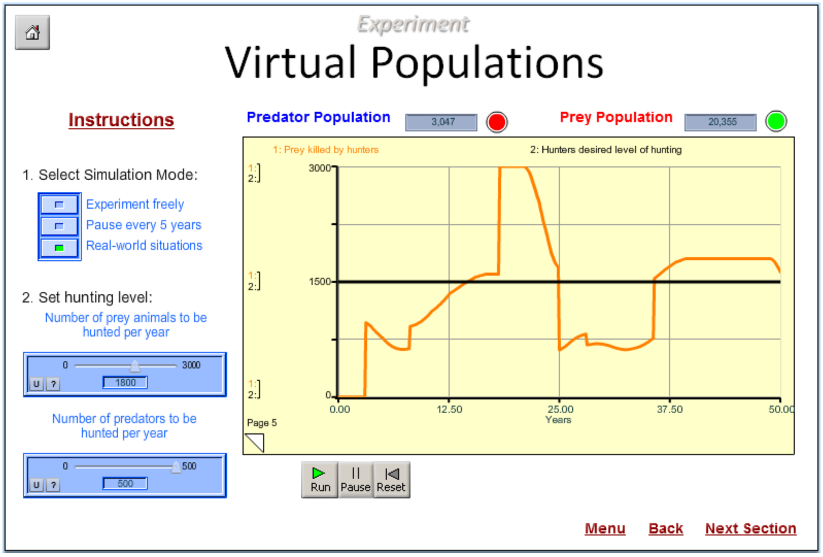

Figure 8: Hunting could not keep pace with the growth of the prey population.

Students' results will vary widely when using this mode of the simulation, just as with using "Pause every 5 years." The important learning comes from being able to articulate what strategy, if any, they were following and if/why it broke down at any point along the way.

Model Structure and Assumptions

The model structure[1] is presented in Figure 9. This screen is accessed via the screen titled "Explore the Model: Model as Hypothesis." Click "Tour the Model Structure" and use the spacebar to toggle through the presentation of the structure.

Notice that there are no outside influences that drive the predator-prey cycles. The green variables are parameters that are set on the Control Panel of the simulation. The remaining variables are defined internally, based on relationships indicated by the red arrows. The variable "Prey consumption of new growth" is colored orange to indicate that it is repeated in two places to avoid stretching a link across the diagram. Click on the link titled "Tour the Loops" (located under "Tour the Model Structure") to read more about the feedback loops embedded in the model structure.

[1] The model presented in this link is actually a simplified version of the model the students simulate. To examine the complete model structure, please download the STELLA file from the Creative Learning Exchange website.

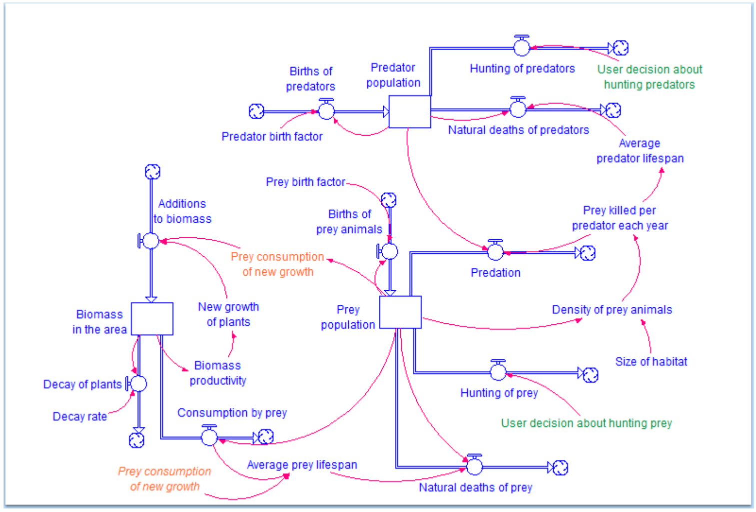

Figure 9: The model structure shown in the "Tour the Model Structure" link.

Limitations of the Model

Lessons 3 – 5 are a mini-series of lessons on population dynamics. The model introduced in Lesson 3 can produce a logistic growth pattern (one population in isolation that bumps against the natural limits of its environment), but cannot be used to represent cyclic population dynamics. It simply lacks the structure (two populations in a balancing feedback loop) necessary to produce oscillation. The model presented in Lesson 4 *does* have the necessary structure to explain a simple hypothesis of predator-prey cycles, but still has limitations because the food supply of the prey population is not represented. In the absence of predators, prey increase to a carrying capacity and are not able to overshoot it.

In Lesson 5, a more complicated view of predator-prey cycles is uncovered. A prey population is shown to exist in a balancing feedback relationship with the biomass as well as with predators. This means that in isolation, without the influence of predators, a prey population could still exhibit an oscillatory behavior pattern. This is likely to manifest itself in extreme situations, such as when predators are suddenly removed due to human intervention in the system, and prey are allowed to grow unchecked. Overshoot, collapse and a recovery marked by oscillation are a plausible result.

This model also has limitations. In areas heavily managed by humans, there may be a complete absence of all predators apart from hunters. In this case, the hunters are the main “predator” population, and a similar oscillatory behavior pattern can appear, such as that shown in the Debrief section of the simulation (Behavior Patterns: Decisions vs. Policies; click the link “A real-life example”). This model is not intended to represent such a situation, although similarities and differences can be discussed in the classroom.

Other limitations are the same as those for Lesson 4. Predators generally have more than one type of prey available to hunt, even in situations where cycles occur with a particular type of prey. Conversely, prey animals often experience pressure from several types of predators, not only one. Many factors affect birth and death rates of both predators and prey, including disease, drought, introduction of invasive species, wildlife management policies, hunting by humans, and so on. The model presented in this lesson is an oversimplification of any *real* predator-prey system, but is an effective representation of a 3-level *general hypothesis* of predator-prey cycles.

Talking Points – Linking the Simulation to Real Life

Some useful questions for discussion with students include the following:

- What other roles from real life might look like the role of Wildlife Manager, where progress must be made toward multiple, often conflicting goals? An example in the area of natural resources could be "dam operator" (allocating water among competing uses), but other examples abound. Mayors/urban planners must balance growth and development with retaining the character of an area (historic buildings, open space, etc.); school administrators must meet state-mandated standards for teaching and respond to national trends, but there are also many local and regional differences that could make the job difficult. Leaders of corporations must balance the drive to release new and innovative products with safety concerns of both workers and customers. Political campaigns, either local or national, could provide plenty of material for such a discussion as well.
- The model shows that creating a "hunting policy" (setting a goal for the size of the prey population, for example, and manipulating hunting levels to achieve that goal) and sticking to it despite pressure from various groups can be very tricky. In reality, wildlife managers probably do a bit of both, regardless of whether they are managing a system that shows predominately oscillating behavior or some other behavior pattern. It is reasonable to assume that they do have goals for the natural resources they manage, but that they must, at times, bow to pressure as well. Students can be prompted to discuss such tradeoffs or asked to research real-life examples (Yellowstone, Kaibab, Isle Royale). It is not necessary to focus on oscillating systems.
- Is there actually a "balance of nature" that would occur naturally if humans did not interfere? If so, what would that balance look like? In models such as the one in this lesson, "dynamic equilibrium" (also called steady-state) occurs when all the levels in the model are unchanging (the inflows match the outflows). Considering the three levels featured in this lesson, how likely is such a situation? What factors could prevent that from happening, or, what would push them out of steady-state if they ever would be in it? Also, students should be prompted to think not only of "events" that might "jiggle the system," but also of important levels that aren't even in the model (the pyramid on the "Real-life Wildlife Management" screen could help here).
- Taking the ideas of the pyramid even further, how likely is it that predator-prey cycles would occur in an area that has many different types of prey for a particular species of predator, or many populations of both types of animals? In other words, are predator-prey cycles more likely to occur when the populations are somewhat isolated geographically or due to the harsh nature of the environment, or in areas with abundant life and many opportunities to migrate?
- When humans attempt to manage a population of wild animals, what are some factors over which they can hope to exercise control? This model features the number of animals that can be hunted as one factor that humans can "control," but students may also have noticed that the

full hunting quota is not always attained. Based on running the simulation model and learning about its structure, what factors can people realistically measure and influence? What factors, in turn, influence the balancing feedback loops that can produce oscillatory behavior?

- Why would population cycles be considered problematic? What kind of population dynamic would hunters like to see (growth, steady-state, decline, cycles) for moose or deer? What about non-hunting outdoor enthusiasts? Farmers? The insurance industry?
- If you had to make an assumption about the general health of the individual animals in the prey population, would you think that the animals are most healthy when the population is growing rapidly, is close to its natural carrying capacity, or experiencing a population crash? What would be your goal in managing a population of prey animals (an ideal behavior-over-time trajectory)? Would you like to see our natural areas include populations of predators as well as prey?

The Cause of the Problem is Within the System

The overall goal of the Oscillation curriculum is to teach a principle of complex systems: The cause of the problem is within the system. Socioeconomic systems that oscillate are often not recognized as oscillating due to their intrinsic structure. Explanations often point to outside influences that are themselves oscillating, or to a particular combination of outside factors believed to drive the oscillation. Yet we know that a physical system such as a spring (presented in Lesson 1) oscillates because it is made to do so. It does not oscillate because a hand or other force continually pushes it in an up-and-down or back-and-forth motion. A spring gets set into motion with a push or a pull, and it oscillates due to its own structure.

Predator-prey systems are well-known real-life examples of biological systems that can oscillate. The cycles can be explained via the internal structure of the relationships of the particular ecosystem. Understanding such systems is the first step in determining how to influence them, if need be, to change the behavior pattern. Because the cause of a system's behavior is due to its structure, changing the behavior pattern is accomplished through changing the structure (rather than eliminating an outside influence). In the case of natural systems, there will always be outside influences that disrupt human management of such systems (drought, disease, fire, etc.). Applying a management policy that accepts the presence of and works to dampen the oscillations (if that is the desired outcome) is an example of changing structure to change the resultant behavior. If the first step of understanding structure is never taken, it is unlikely that efforts to produce change will move beyond placing blame on outside forces that "cause" the problem.

Remaining lessons in this series illustrate these ideas using oscillating systems in human health (Burnout cycles) and economics (Commodity cycles).